

TITLE OF THE INVENTION

APPARATUS FOR AND METHOD OF GENERATING OPTICAL RECORDING PULSE

CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of Korean Application NO. 2001-8136, filed February 19, 2001, in the Korean Industrial Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

**[0002]** The present invention relates to an apparatus for and a method of generating an optical recording pulse, and more particularly, to an apparatus for and a method of generating an optical recording pulse having multi-pulse patterns suitable for a high-density and high-speed optical medium.

2. Description of the Related Art

**[0003]** An optical recording pulse having multi-pulse patterns is designed to overcome the disadvantages of a mark edge recording method that enables recording signals to be recorded on an optical medium with high recording density. A mark is formed on the optical medium in response to the recording signals. If the mark is long enough to have a high thermal density when the recording signals are recorded on the optical medium using the mark edge recording method, the high thermal density causes a trailing edge of the mark to have a width greater than a leading edge of the mark. The widened trailing edge of the mark results in degradation of the optical recording signals recorded on the optical medium when the optical recording signals are reproduced from the optical medium. As a solution to the problem, the optical recording pulse having multi-pulse patterns is suggested. The optical recording pulse corresponding to the recording signal includes multi-pulse chains or multi-pulse trains (hereinafter referred to multi-pulse).

**[0004]** The optical recording pulse having multi-pulse patterns is generated as shown in FIG. 1B when Non Return to Zero Inverted (NRZI) data of FIG. 1A is inputted. As shown in FIG. 1B, the optical recording pulse having the multi-pulse patterns has three levels, that is, a recording power level, an erase power level, and a bias power level. The optical recording pulse having the multi-pulse patterns includes an erase pulse, a first pulse, a multi-pulse, a last pulse, and a cooling pulse.

**[0005]** FIG. 1B shows a bottom bias power level. However, a basic bias power level corresponding to an erase power level shown in FIG. 1B or an intermediate bias power level which is between the erase power level and a bias power level may be provided for a stable recording operation. If the basic and intermediate power levels in addition to the bottom-level bias power are also considered as bias power levels, the number of the bias power levels would be 3.

**[0006]** The erase pulse having the erase power level is used to erase a previous record or perform pre-heating before a recording signal is recorded. The first pulse has the recording power level and is designed to create the leading edge of a recording mark. With regard to a long mark, the multi-pulse is designed to reduce the unevenness of the domain, which may be caused by the thermal density. If the optical medium is a DVD-RAM or a DVD-R, the multi-pulse is inserted into the optical recording pulse having a length of  $5T$  of the NRZI. If the optical medium is a DVD-RW or a CD-RW, the multi-pulse is inserted into the optical recording pulse having a length of  $4T$  of NRZI.  $T$  designates a predetermined clock period for the optical recording signal.

**[0007]** The multi-pulse is inserted between the first pulse and the last pulse when the mark is created. The pulses of the multi-pulse alternate between the bottom bias power level and the recording power level. The number of pulses in the multi-pulse is determined based on the length of the recording mark. For example, in the case of a DVD-RAM or a DVD-R, the number of the pulses of the multi-pulse is obtained from a value corresponding to the length of  $4T$  of the NRZI. In the case of a DVD-RW or a CD-RW, the number of the pulses of the multi-pulse is obtained from a value corresponding to the length of  $3T$  of the NRZI.

**[0008]** The last pulse is used to create the trailing edge of the recording mark and has the recording power level. The cooling pulse has the bias power level, and is used to prevent the recording mark from being formed too long and being distorted. Therefore, in a cooling pulse

section, a laser power is turned off in accordance with the cooling pulse. The bias power level attained by the cooling pulse can be the basic bias power level corresponding to the erase power level, the bottom bias power level, or the intermediate bias power level between the erase power level and the bottom level.

**[0009]** However, when the optical medium is initialized, the width ( $T_{MP}$ ) of the multi-pulse has a fixed value as shown in 11T of FIG. 1B. Therefore, there is a limit in obtaining an ideal domain configuration of the mark formed on the optical medium.

**[0010]** To record the NRZI data shown in FIG. 2A on a phase-transformation optical medium, the optical recording pulse having multi-pulse patterns are inputted to a laser diode (LD) unit. The LD unit determines a power level based on the input pulse and heats a recording film of the optical medium. As shown in FIG. 2B, the recording film of the optical medium is in an erase state around 300°C and in a liquid state or a melting state if the temperature of the recording film rises above 600°C. Then, the cooling speed of the recording film is adjusted so that a desired mark can be formed. Lowering or turning off the power of the laser beam in response to the cooling pulse may effectively cool the recording film. In FIG. 2B, a horizontal axis indicates time, and a vertical axis indicates the temperature of the recording film of the optical medium.

**[0011]** A domain is created on the recording film of the optical medium by a recording procedure as shown in FIG. 2B. The created domain configuration is shown in FIG. 2D. FIG. 2D shows that the leading edge and the trailing edge of the mark on the domain are uneven and unlike the ideal domain configuration shown in FIG. 2C.

**[0012]** The domain corresponds to the mark or a pit formed on the optical medium. Therefore, unless the first, middle, and last portions of the domain configuration are formed evenly and smoothly, jitter increases, and cross erasure of a gap between adjacent tracks occurs. Moreover, cross talk is generated between adjacent tracks during reproduction of the optical recording pulse. The above problems are more serious for a high-density and high-speed optical medium or a land/groove structure optical medium.

## SUMMARY OF THE INVENTION

**[0013]** To solve the above problems, it is an object of the present invention to provide an apparatus for and a method of generating an optical recording pulse having multi-pulse patterns suitable for a high-density, high-speed optical medium.

**[0014]** It is another object of the present invention to provide an apparatus for and a method of generating an optical recording pulse having multi-pulse patterns, wherein each width of the pulses of a multi-pulse chain is set to be variable depending on the type of the optical medium, the recording speed, or a constant angular velocity (CAV) recording process.

**[0015]** Additional objects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

**[0016]** To achieve the above and other objects, an apparatus is provided for generating an optical recording pulse having a first pulse, a multi-pulse chain having a plurality of patterns, and a last pulse according to the present invention, the apparatus including a recording pulse generator generating an optical recording pulse and a controller controlling the recording pulse generator so that the recording pulse has pulses of the multi-pulse chain having at least two different widths to create one mark according to the type of the optical medium or the set recording speed.

**[0017]** In addition, the controller determines whether the pulses having at least two different widths should exist on the multi-pulse chain of the optical recording pulse. Moreover, it is preferable that the controller determines the widths of the multi-pulse chain in response to the type of the optical medium, the recording speed, and the CAV recording process during the initialization of a recording process.

**[0018]** To achieve the above and other objects, a method is provided of generating an optical recording pulse having a first pulse, a last pulse, and a multi-pulse chain having a plurality of patterns, and a last pulse according to the present invention. The method includes setting a recording mode so that at least two different widths of the multi-pulse chain are used to create one mark depending on the type of an optical medium or the recording speed, and generating an optical recording pulse according to the set widths of the respective pulses of the multi-pulse chain.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0019]** These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

**[0020]** FIGs. 1A and 1B are waveform diagrams of an optical recording pulse having multi-pulse patterns;

FIGs. 2A through 2D are examples showing recording characteristics of an optical medium when the optical recording pulse of FIG. 2B is used for forming a mark;

FIG. 3 is a block diagram of an optical recording pulse generating apparatus constructed according to an embodiment of the present invention;

FIGs 4A through 4E show examples of waveforms of the optical recording pulse generated according to an embodiment of the present invention;

FIGs 5A, 5B, 5C, and 5D are examples showing recording characteristics of the optical medium according to the present invention; and

FIG. 6 is a flowchart describing an optical recording pulse generation method according to an embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0021]** Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below in order to explain the present invention by referring to the figures.

**[0022]** Referring to FIG. 3, an optical recording pulse generating apparatus constructed according to the present invention includes a controller 301, a Non Return to Zero Inverted (NRZI) detector 302, a recording pulse generator 303 and a Laser Diode (LD) driver 304.

**[0023]** If an optical medium is inserted into an optical recording apparatus, the controller 301 identifies the type of the optical medium by reading information from a lead-in area and a lead-

out area of the optical medium. The type of the optical medium can be identified through a recording speed and the type of a recording pulse. For example, if different recording pulses are generated depending on whether a DVD-RAM, DVD-R, DVD-RW, DVD+RW or CD-RW is inserted, the controller 301 identifies whether the optical medium is one of a DVD-RAM, DVD-R, DVD-RW, DVD+RW and CD-RW. However, in the case where the recording pulses are generated according to a manufacturer's specification or other detailed conditions, the type of the optical medium can be identified through the detailed conditions. The controller 301 determines a recording speed suitable for the type of the optical medium identified through the detailed conditions.

**[0024]** After the controller 301 identifies the type of the optical medium and determines the recording speed, the controller 301 generates initial values used for initiating a recording and reproducing function on the optical medium. The initial values include values corresponding to the multi-pulse patterns of the optical recording pulse. In particular, the controller 301 determines the respective widths ( $T_{MP}$ ) of the pulses of the multi-pulse depending on the type of the optical medium, the recording speed, and the CAV recording process.

**[0025]** In this case, the controller 301 sets the width ( $T_{MP}$ ) of each pulse of the multi-pulse to a fixed value or to at least two different values. In the case where at least two different values are set as the widths of the multi-pulse, the controller 301 determines how two different widths should be assigned to respective pulses of the multi-pulse.

**[0026]** For example, it is assumed that the widths of the first four pulses of the multi-pulse chain are larger than a pre-fixed value, and the widths of the remaining pulses of the multi-pulse chain are smaller than the pre-fixed value. In this case, if the NRZI data shown in FIG. 4A is input, the optical recording pulse is generated according to an embodiment of FIG. 4B. The first four pulses of the multi-pulse chain have widths ( $T_{MP1}$ ) larger than the pre-fixed value. The remaining pulses of the multi-pulse chain, however, have widths ( $T_{MP2}$ ) smaller than the pre-fixed value.

**[0027]** In addition, it is assumed that the width of an initial pulse within the multi-pulse chain is greater than the pre-fixed value, the width of an ending pulse of the multi-pulse chain is less than the pre-fixed value, and the widths of middle pulses between the initial pulse and the ending pulse of the multi-pulse chain are set to be the pre-fixed values. In this case, if the NRZI data shown in FIG. 4A is input, the optical recording pulse according to another embodiment of

FIG. 4C is generated. That is, as shown in FIG. 4C, the initial pulse of the multi-pulse chain has a width ( $T_{MP1}$ ) larger than the pre-fixed value, the ending pulse of the multi-pulse chain has a width ( $T_{MP3}$ ) narrower than the pre-fixed value, and the middle pulses between the initial pulse and the ending pulse of the multi-pulse chain have a width ( $T_{MP2}$ ) which is the same as the pre-fixed value.

**[0028]** In another case, it is assumed that the width ( $T_{MP}$ ) of the initial pulse within the multi-pulse chain is larger than the pre-fixed value, and the widths ( $T_{MP}$ ) of the remaining pulses are the same as the pre-fixed value. In this case, if the NRZI data shown in FIG. 4A is input, the optical recording pulse according to another embodiment of FIG. 4D is generated. That is, as shown in FIG. 4D, the initial pulse of the multi-pulse chain has a width ( $T_{MP1}$ ) greater than the pre-fixed value, and the remaining pulses of the multi-pulse chain have widths ( $T_{MP2}$ ) the same as the pre-fixed value.

**[0029]** In addition, it is assumed that the width of the initial pulse within the multi-pulse chain is smaller than the pre-fixed value, and the widths of the remaining pulses are the same as the pre-fixed value. In this case, if the NRZI data shown in FIG. 4A is input, the optical recording pulse according to another embodiment of FIG. 4E is generated. That is, as shown in FIG. 4E, the initial pulse of the multi-pulse chain has a width ( $T_{MP1}$ ) smaller than the pre-fixed value, and the remaining pulses of the multi-pulse chain have widths ( $T_{MP2}$ ) the same as the pre-fixed value.

**[0030]** Besides the cases illustrated in FIGs. 4A through 4E, the multi-pulse chain can be divided into a first part and a second part. In the first and second parts, the widths of the pulses of the multi-pulse chain can be set to be different from each other.

**[0031]** As described above, if the width ( $T_{MP}$ ) of the pulse of the multi-pulse chain is set to be variable, the variable pulses of the multi-pulse chain should not exceed a predetermined range of the multi-pulse chain of the optical recording pulse. That is, although the width of the respective pulses of the multi-pulse chain varies, and the total period of the multi-pulse chain and the number of the pulses of the multi-pulse chain in the optical recording pulse are maintained.

[0032] Moreover, the pulse width ( $T_{MP}$ ) within the multi-pulse chain should be set in such a way that the configuration of the domain created on the optical medium will be nearly close to the ideal configuration as shown in FIG. 5C in all cases.

[0033] In response to the NRZI data as shown in FIG. 5A, the width ( $T_{MP}$ ) of the pulses of the multi-pulse chain is determined in such a way that the NRZI data of FIG. 5A may have the recording characteristics illustrated by the dot lines of FIG. 5B. Regardless of the optical medium used, the actual domain, as shown in FIG. 5D, should have a configuration close to that of the ideal domain of FIG. 5C.

[0034] During setup of initial values, the controller 301 may change each starting value ( $T_{smp}$ ) for the pulses of the multi-pulse chain or each ending value ( $T_{EMP}$ ) of the pulses of the multi-pulse in order to adjust the width of the pulses of the multi-pulse chain. For example, in FIG. 4, the controller determines widths  $T_{MP1}$ ,  $T_{MP2}$ , and  $T_{MP3}$  and the ending values  $T_{EMP1}$ ,  $T_{EMP2}$ , and  $T_{EMP3}$  of the pulses of the multi-pulse chain.

[0035] When the NRZI detector 302 receives the NRZI data, the NRZI detector 302 detects the type of data to be recorded. That is, the NRZI detector 302 detects the relation between the current mark and the space, and the sizes of the current mark or the space depending on the size of spaces before and after the current mark. Then, the detector 302 provides the detected results to the recording pulse generator 303.

[0036] The recording pulse generator 303 generates an optical recording pulse corresponding to the detected results provided by the NRZI detector 302 and the initial values of the optical recording pulse provided by the controller 301. That is, the recording pulse generator 303 generates the optical recording pulse having any of the forms shown in embodiment of FIGS. 4B through 4E depending on the initial values provided by the controller 301.

[0037] The LD driver 304 operates the LD (not shown) according to the recording pulse provided by the recording pulse generator 303.

[0038] FIG. 6 is a flowchart of the optical recording pulse generation method according to the present invention.



**[0039]** If it is determined that an optical medium is inserted in operation 601, the type of optical medium is discriminated in operation 602. The discrimination criteria are the same as those of the controller 301. Then, in operation 603, the current recording speed is determined. The recording speed can be user-defined or predetermined.

**[0040]** In operation 604, initial values are set up depending on the type of optical medium and the recording speed. In this case, the values of the pulses included in the multi-pulse patterns of the optical recording pulse are also set up. In particular, as described above, the controller 301 can set each width of the pulses within the multi-pulse chain as one value or at least two different values. In the operation, where the one value or the two different values should be assigned within the multi-pulse chain is determined. For example, as shown in FIGS. 4B through 4E, it is determined that the width of the first N pulses of the multi-pulse chain is set to be  $T_{MP1}$  while that of the remaining pulses of the multi-pulse chain is set to be  $T_{MP2}$  within the multi-pulse chain, and it is determined widths of the respective pulses of the multi-pulse chain can be arranged in order.

**[0041]** If the initial values and the recording mode are set up completely, the optical recording pulses are generated in operation 606 according to the values set during the initialization. The generated optical recording pulse is as shown in FIG. 4B through 4E.

**[0042]** In operation 607, if it is determined that the recording has not been completed in operation 607, operation 606 is performed again so that the optical recording pulse can be generated according to the set conditions. However, if it is determined that the recording has completed in operation 607, the recording mode is changed to the reproduction mode in operation 608.

**[0043]** The present invention generates optical recording pulses where multi-pulses have one pulse width or at least two different pulse widths within the multi-pulse chain depending on the type of the optical media, the recording speed, or the CAV recording process. Then, the configuration of the domain created on the optical media will be nearly close to that of the ideal domain. Jitter will be reduced and cross erasure between adjacent tracks, which may be caused by the domain configuration, will be prevented in any high-density, high-speed recording environments. In addition, cross-talk between adjacent tracks, which may be generated due to the domain configuration during reproduction, can be prevented.

[0044] Although a few preferred embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes are made in this embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and equivalents.